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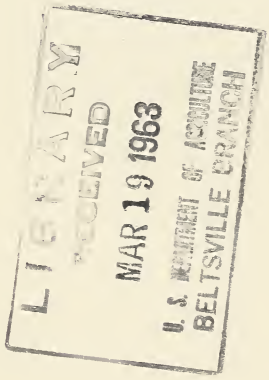

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FEEDING PELLETED RATIONS TO BEEF CATTLE

By P. A. Putnam and R. E. Davis, *Beef Cattle Research Branch, Animal Husbandry Research Division, Agricultural Research Service*

INTRODUCTION AND REVIEW OF LITERATURE

The pelleting of various feeds or rations for ruminants is a dominant topic in current trade and agricultural periodicals. Pelleting of rations has been said to facilitate mechanization of feeding, conserve storage space, reduce waste, and improve animal performance. Although nutritional benefits resulting from feeding rations in a pelleted form are not completely understood, certain responses have been consistently observed and possible explanations for these trends have been presented and discussed.

This report presents an introduction to the popular and technical literature on pelleting and combines and summarizes information concerning the feeding of pelleted rations to beef cattle from work conducted by the Beef Cattle Research Branch at field and cooperating stations and at Beltsville, Md.

Samples of the current thinking in respect to pelleted rations for beef cattle may be obtained from the articles by Neumann, Webb, and Cmarik (*74*),[1] Elrod (*36*), Dudley (*33*), Davis (*27*), Loosli (*64*), and Cunha (*25, 26*). Allen (*5, 6*) has discussed pelleting from the viewpoint of feed manufacturers. Cunha (*25, 26*) has presented a list of established facts about pelleted feeds and predicts an increasing use of pellets. Dudley (*33*) has surveyed western feeders and estimated that 3.4 percent of them were feeding completely pelleted rations. Other summaries have been presented by Meyer (*69*), Boren (*13*), Rhodes, Woods, and Burroughs (*83*), Minson (*71*), and Tillman (*89*).

The engineering aspects of pelleting have been discussed by Bruhn (*19*), Bruhn, Zimmerman, and Niedermeir (*20*), Dobie (*30, 31*), and Butler and McColby (*21*). Guslafson (*40*) has reported on a durability test as a key for handling pellets and Heideman (*43*) has discussed the handling and mixing of up to 65-percent molasses in pelleted feeds.

Various workers (*11, 48, 54, 84, 92*) have cited estimated costs of pelleting. Their estimates have ranged from $2.50 for pelleting up to $15.00 for grinding, mixing, and pelleting an all roughage ration. Rhodes, Woods, and Burroughs (*83*) have estimated that "break-even" prices for pelleting range from $2 to $8 per ton, depending upon the roughage content of the ration.

Another area of interest is the development of portable field-pelleting equipment (*1, 2, 3*). It has been predicted that successful

[1] Italic numbers in parentheses refer to Literature Cited, p. 22.

and economical "wafer" producing machinery will be available to the farmer in the near future.

Nutritionally, the responses to pelleting are best considered relative to the proportion of roughage in the rations being studied. The feeding of pelleted roughages has resulted in a marked and consistent improvement in animal performance. In recent reports Boren (*14*), Wallace and Hubbert (*93*), Webb and Cmarik (*94*), Stangel et al. (*87*), Miller et al. (*70*), Logan, Jones, and Lyerly (*63*), Jones et al. (*52*), Ittner, Meyer, and Lofgreen (*49*), Hogan et al. (*45*), Dinusson et al. (*29*), Berry (*11*), and Cmarik, McKibben, and Webb (*24*) have noted increased consumption and increased bodyweight gains when beef cattle were fed roughages in pelleted form as compared with performance when fed chopped or long forage. However, Klosterman et al. (*57*, *58*, *59*) observed little advantage in gains and the costs were more when pelleting alfalfa as compared with fine grinding. Kolari et al. (*60*) observed no difference in gains when feeding hay, ear corn, or both as pellets. Brown et al. (*17*) fed a roughage-molasses ration and observed better and more efficient gains when the ration was not pelleted.

The feeding of high-concentrate rations in pelleted form has not resulted in nearly so spectacular benefits as with roughages, but certain advantages have been observed. Logan, Jones, and Lyerly (*63*), Woods and Rhodes (*97*), Foster, Galgan, and Ensminger (*38*), Baker et al. (*8*), Dyer (*34*), Beardsley (*9*, *10*), Weir et al. (*95*), Perry, Whitfield, and Beeson (*75*), Garrigus et al. (*39*), Williamson et al. (*96*), and Berry (*11*) observed decreases in the amount of feed required per pound of gain when mixed rations were pelleted.

Clanton, Peden, and Matsushima (*23*), and Kercher (*55*, *56*) reported equal gains and feed efficiency by steers on pelleted and ground rations.

Kolari et al. (*60*) observed increased gains and feed efficiency when the hay part of a ration was pelleted, but when the ear corn part was pelleted, performance was inferior to that when it was ground. Pope et al. (*76*, *77*) observed that less feed was required per pound of gain when milo was pelleted rather than rolled.

Feeding pellets of various sizes had no effect on gains of fattening lambs according to Church and Fox (*22*). Brown et al. (*17*, *18*), England and Taylor (*37*), and Hentges and Alexander (*44*) could demonstrate no advantage for the feeding of a pelleted ration.

Several other aspects have been studied in relation to possible effects of pelleting a ration. Sodium bentonite, a binding agent, reacts chemically with vitamin A and beta carotene as reported by Laughland (*61*). Dewey, Lee, and Marston (*28*) provided trace mineral supplementation by using a pellet of high specific gravity. The preliminary results of Swahn and Rutqvist (*88*) suggested that certain types of steaming in conjunction with "warm pelleting" could prove effective as a "pasteurization" method. Robbins et al. (*85*) studied the effect of pelleting upon the incidence of urinary calculi in lambs. Consumption of pelleted feeds by lambs and the incidence of rumen parakeratosis were related by Jensen et al. (*51*). Hopkins, Fontenot, and Mestanza (*47*) also observed more rumen parakeratosis in pellet-fed lambs. Others have noted changes in the rumen papellae

(*32*).[2] Elam, Putnam, and Davis (*35*) and Bradley et al. (*15*) incorporated chromic oxide in pelleted complete rations to estimate digestibilities.

The effect of the pelleting process on the subsequent metabolism of rations by livestock has received considerable attention. Brown et al. (*17*) observed a decrease in fat digestion, although Lindahl and Reynolds (*62*, *82*) observed an increase in the apparent digestibility of the ether extract. Clanton, Peden, and Matsushima (*23*) and Alexander et al. (*4*) observed decreases in the digestibility of pelleted rations.

Blaxter and Graham (*12*) reported a lower TDN and digestible and metabolizable energy in pelleted, ground grass hay. Net energy values were unchanged. Meyer (*68*), using sheep, observed an increase in nitrogen digestibility when pelleted alfalfa was fed. TDN and metabolizable and net energy were not affected. He surmised that fine grinding before pelleting is a major factor governing increased feed intakes and that pelleting serves to put dusty feed in a more palatable form when feeding sheep a roughage ration.

That instantaneous temperatures during pelleting may exceed 225° F. was reported by Wornick (*98*, *99*). Jahn and Kamstra (*50*) used *in vitro* methods to study the effects of temperature and pressure on feed utilization. According to Kamstra, LeFevre, and Jahn (*53*) the *in vitro* results suggested that pelleting increased the digestibility of low-quality roughages.

Allred et al. (*7*), working with chicks, concluded that both a physical and nonphysical change occurred during the pelleting process. Mitchell and Goff (*72*) observed no improvement in growth rate or feed utilization when broilers were fed reground pellets.

Hawkins (*42*) reported more water-soluble nutrients in pelleted concentrates than in meal, and Lindahl and Reynolds (*62*) reported an increase in the percentage of ether extract when alfalfa was pelleted. Chemical studies indicated that gas production, total solubles, reducing sugars, and soluble starch were highest in pelleted and lowest in steam-crimped grains, according to Hastings and Miller (*41*). Pressure involved in pelleting apparently causes changes in the starch structure, according to the last workers.

Other investigators observed marked changes in chemical composition (*86*, *91*) and decreased nutritive value (*16*, *46*) when feeds or forages were heated.

RESULTS

Front Royal, Va., 1956–57

One of the earlier studies where steers were fed a complete, pelleted ration was conducted by Priode (*78*) during the 1956–57 winter feeding season at Front Royal.

The composition of the ration was as follows:

Feed used:	*Percent*
Corn and cob meal	60
Linseed meal	5
Cottonseed meal	5
Ground alfalfa meal	15
Ground orchardgrass hay	15

[2] Anderson, W., and Lindahl, I., 1961. Unpublished.

The performance of steers group-fed this ration, either ground, pelleted, or as long hay and grain, is shown in table 1. The concentrate-to-roughage ratio was 3:2. The average gains were the same for the animals on the pelleted and ground rations, but the pellet-fed group consumed 10.4 percent less feed. The long hay-fed group consumed the least feed and gained the least weight.

TABLE 1.—*Performance of beef steers fed ground, pelleted, and long hay and grain rations*

Treatment	Steers	Initial weight	Final weight	Total gain	Average daily gain [1]	Slaughter grade	Feed per day	Feed per pound of gain
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*		*Pounds*	*Pounds*
Ground hay and grain mixed	20	493	907	414	2. 11	Choice—	22. 2	10. 4
Pelleted	20	489	906	417	2. 13	Choice—	19. 9	9. 3
Long hay and grain.	18	500	854	354	1. 81	Choice—	19. 3	10. 6

[1] 196-day feeding period from Nov. 14, 1956, to May 29, 1957.

Tifton, Ga., 1958–60

Two feeding trials [3] were conducted at Tifton, Ga., 1958–60, to determine the effect on steer performance of feeding pelleted or unpelleted fattening rations varying in concentrate-to-roughage ratios (*9*). The composition of the rations was as follows:

	Lot No.			
Feeds used:	*1* (*percent*)	*2 and 3* (*percent*)	*4 and 5* (*percent*)	*6 and 7* (*percent*)
Ground snapped corn	79. 0	75. 0	53. 6	32. 1
Cottonseed meal	15. 0	12. 5	12. 5	12. 5
Blackstrap molasses	6. 0	5. 0	5. 0	5. 0
Coastal bermudagrass hay	([1])	7. 5	28. 9	50. 4

[1] *Ad libitum.*

Rations of lots 3, 5, and 7 were fed in the form of a $^{1}\%_{64}$-inch pellet after the ingredients were ground through a ⅛-inch screen. A maximum temperature of 120° F. was reported. The unpelleted rations were ground through a $\%_{16}$-inch screen.

The results of the two trials have been averaged and are summarized in table 2.

[3] Georgia Coastal Plain Experiment Station, Cooperative Animal Husbandry Investigations, Annual Report 1958–59, 1959–60.

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TABLE 2.—*Performance of steers fed pelleted and unpelleted rations varying in proportions of concentrates and roughages* [1]

Lot number and concentrate: roughage ratio	Form fed	Initial weight	Final weight	Total gain	Average daily gain	Carcass grade	Feed per day	Feed per pound of gain
		Pounds	*Pounds*	*Pounds*	*Pounds*		*Pounds*	*Pounds*
1—66:33	Long hay and grain	733	1, 120	387	2. 75	Good+	28. 7	10. 4
2—70:30	Ground	728	1, 123	395	2. 81	Good	27. 6	9. 8
3—70:30	Pelleted	735	1, 086	351	2. 50	Good	22. 0	8. 8
4—55:45	Ground	730	1, 099	369	2. 63	Good	27. 0	10. 3
5—55:45	Pelleted	735	1, 106	371	2. 64	Good	24. 0	9. 1
6—40:60	Ground	736	1, 072	336	2. 39	Good—	26. 4	11. 0
7—40:60	Pelleted	732	1, 111	379	2. 70	Good—	26. 0	9. 6

[1] 18 steers per treatment group.

Pelleting a high-roughage ration increased gains and feed efficiency, while only feed efficiency was increased when a high-concentrate ration was pelleted. Carcass grades were higher for the lots on the higher concentrate rations. Steers on the finely ground and pelleted rations failed to ruminate or ruminated only slightly.

Fort Reno, Okla., 1959–60

While the trials were in progress at Tifton, similar aspects of the problem were being studied at the Fort Reno Beef Cattle Research Station in Oklahoma in 1959–60. These studies were carried out in cooperation with the Oklahoma State University (McCroskey et al., *65*, *66*, *67*).

The studies were concerned with the effect of the proportion of roughage in the ration and the response to pelleting. The following rations (McCroskey, Pope, and Urban, *65*, *66*) containing concentrate-to-roughage ratios of 1:4 and 4:1 were compared.

Feeds used:	Concentrate:roughage ratio 1:4 (*percent*)	4:1 (*percent*)
Ground milo	1. 0	65. 1
Cottonseed meal	12. 0	7. 0
Molasses	7. 0	7. 0
Cottonseed hulls	40. 0	10. 0
Chopped alfalfa	40. 0	10. 0
Ground limestone	------	. 9

The results (table 3) showed little or no advantage in average daily gain when feeding a pelleted high-concentrate ration, but the feed required per unit gain was less. Increased gains, consumption, and feed efficiency were observed when feeding the high-roughage ration in a pelleted form. Furthermore, a ration with a concentrate-to-roughage ratio of 4:1 was fed as a meal, pelleted and reground, and pelleted, *ad libitum* and limited. The results (table 4) were interpreted as suggesting that the increase in gains because of pelleting was due primarily to increased feed efficiency and feed intake.

TABLE 3.—*Effect of pelleting rations with different concentrate-to-roughage ratios* [1]

Concentrate:roughage ratio	Treatment	Steers	Average daily		Feed per pound of gain
			Gain	Feed	
		Number	*Pounds*	*Pounds*	*Pounds*
1:4	Meal	12	1. 88	23. 2	12. 31
	Pelleted	12	2. 30	26. 8	11. 62
4:1	Meal	12	2. 33	22. 2	9. 52
	Pelleted	12	2. 25	19. 9	8. 80

[1] Averaged from McCroskey, Pope, and Urban (*65*, *66*).

In an earlier report Urban, Pope, and Stephens (*90*) noted a reduction in feed intake, gains, and an increased cost per unit gain when

TABLE 4.—*Effect of the physical form of a 1:4 concentrate-to-roughage ratio fed to steer calves* [1]

Treatment	Steers	Initial weight	Final weight	Gain	Average daily		Feed per pound of gain
					Gain	Feed	
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Meal	6	483	730	247	1. 89	23. 0	12. 13
Reground pellets	6	470	750	280	2. 14	24. 2	11. 22
Pellets	6	483	763	280	2. 14	23. 8	11. 07
Limited pellets	6	483	739	256	1. 96	21. 3	10. 63

[1] McCroskey, Pope, and Urban (*66*).

barley was fed in a pellet. An explanation of these results was not proposed.

Beltsville, Md., 1950–52

Initial studies of pelleting rations, conducted at Beltsville, 1950–52, under the supervision of I. Lindahl [4] and R. E. Davis, indicated that temperatures imposed when pelleting concentrate rations reached 138° to 142° F.

Studies were also conducted to determine the effects of variations in feedstuffs on pellet stability. Cottonseed meal and regular-grind alfalfa meal were used as base materials to which other feedstuffs were added. The materials were pelleted (⅝-inch die) with and without steam and stored for 1 week before any measurements were taken. A crushing index was obtained by measuring the pressure necessary to crush a pellet 15 mm. in length. A breaking index was determined by measuring the pressure necessary to break the pellet when a round-edged, 2-mm. shear bar was applied to the center of the pellet when the pellet was suspended over a 10 mm. opening. Some of the results are given in tables 5 and 6.

Beltsville, Md., 1959–60

A ration similar to the Front Royal ration was fed individually to steers at Beltsville in 1959–60 (Putnam and Davis, *80*). It was offered in ground and pelleted forms as a mixture or with the grain and roughage portion offered separately but with the concentrate-to-roughage ratio being maintained constant. The results with the following ration are summarized in table 7.

Feeds used:	*Percent*
Corn, cracked	48
Linseed meal	5
Cottonseed meal	5
Alfalfa hay	21
Timothy hay	21

[4] Lindahl, I. 1952. Animal Husbandry Research Division, U.S.D.A., 3rd Quarterly Progress Report.

TABLE 5.—*Effect of adding various feedstuffs to cottonseed meal on the quality of the pellets produced during regular pelleting operations*

Ingredients	Crushing index [1]		Breaking index [1]	
	No steam [2]	Steam [2]	No steam [2]	Steam [2]
Cottonseed meal (expeller process):				
100%	----	34±8	----	11±4
90% + molasses 10%	28±9	42±7	23±4	34±5
45% + molasses 10% + alfalfa meal 45%	49±11	59±8	26±6	41±4
50% + wheat middlings 50%	----	50±7	----	27±9
80% + molasses 20%	66±8	----	39±8	----
50% + soybean oil meal 50%	----	41±10	----	19±10
50% + distillers solubles 50%	----	[3] 33±4	----	28±7
50% + peanut meal 50%	----	36±4	----	14±2
50% + ground corn 50%	----	15±4	----	5±1
50% + pulverized oats 50%	----	17±6	----	6±1
50% + rolled oats 50%	----	21±3	----	6±2
50% + ground barley 50%	----	21±8	----	7±2
50% + ground wheat 50%	----	20±3	----	7±2
50% + ground milo 50%	----	30±11	----	12±4
50% + wheat bran 50%	----	74±8	----	21±5
45% + molasses 10% + wheat bran 45%	35±6	41±5	21±4	28±5

[1] Higher numerical values indicate greater resistance to crushing or breaking.
[2] Leaders indicate that suitable pellets were not produced under these conditions.
[3] Only a trace of steam can be used.

TABLE 6.—*Effect of adding various feedstuffs to alfalfa meal on the quality of the pellets produced during regular pelleting operations*

Ingredients	Crushing index [1]		Breaking index [1]	
	No steam [2]	Steam [2]	No steam [2]	Steam [2]
Alfalfa meal (regular grind):				
100%	85±20	([3])	26±13	([3])
90% + molasses 10%	76±10	----	43±7	----
50% + wheat middlings 50%	----	110±17	----	42±7
45% + molasses 10% + wheat middlings 45%	60±19	95±13	25±10	41±6
80% + molasses 20%	72±8	([3])	41±9	([3])
50% + soybean oil meal 50%	47±28	([3])	21±13	([3])
50% + corn gluten meal 50%	56±7	65±9	27±6	30±9
50% + cottonseed meal 50%	----	101±6	----	45±8
50% + ground corn 50%	----	37±9	----	10±3
50% + pulverized oats 50%	----	31±4	----	12±3
50% + ground rolled oats 50%	----	41±10	----	25±6
50% + ground barley 50%	----	65±11	----	28±5
50% + ground wheat 50%	----	79±11	----	37±8

[1] Higher numerical values indicate greater resistance to crushing or breaking.
[2] Leaders indicate that suitable pellets were not produced under these conditions.
[3] Data are incomplete.

TABLE 7.—*Performance of beef steers fed ground vs. pelleted and mixed vs. separate rations*

Treatment	Steers	Initial weight	Final weight	Total gain	Average daily gain [1]	Slaughter grade	Carcass grade	Feed per day	Feed per pound of gain
Ground:	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*			*Pounds*	*Pounds*
Mixed	6	778	1,064	286	2.32	Choice−	Good+	22.0	9.47
Separate	6	751	1,044	293	2.71	Good+	Good+	24.8	9.14
Pelleted:									
Mixed	6	754	1,041	287	2.51	Good+	Good+	21.2	8.46
Separate	6	770	1,059	289	2.57	Good+	Good+	20.3	7.90

[1] Calculated from regression of weekly weights during 112-day feeding period.

TABLE 8.—*Carcass data on steers fed pelleted and nonpelleted rations* [1]

Treatment	Steers	Cold carcass weight	Dressing	Rumen [2]	Heart [2]	Liver [2]	Lung [2]	Ruffle fat [2]	Reticulo-rumen [3]
	Number	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Pelleted	12	623	60. 0	2. 82**	0. 71**	2. 01***	0. 94	1. 56	31. 6*
Ground	12	630	60. 4	2. 47**	. 63**	1. 78***	. 88	. 88	29. 4*

[1] Significantly different: *=$P<0.10$; **=$P<0.05$; ***=$P<0.01$.
[2] Values expressed as a percentage of cold carcass weight.
[3] Values expressed as a percentage of gastrointestinal tract weight.

There were no differences in average daily gains, but the pounds of feed consumed for each pound of gain were significantly less for the animals consuming the pelleted rations. Since feed intake was not increased by pelleting, a physical or chemical change may have occurred as suggested by Allred et al. (*7*). Wastage was not considered a factor, as the animals were individually fed in deep mangers. However, since the hay fed to the groups receiving the nonpelleted rations was coarsely ground (1-inch screen), there was a marked difference in particle size when the rations were pelleted.

The average slaughter and carcass grades were slightly higher (1/6 grade) for the animals that consumed the ground rations.

Carcass and slaughter information revealed no differences in dressing percentage, but steers fed the pelleted ration did have significantly heavier rumens, livers, and hearts (table 8). Their lungs also appeared to be larger and the amount of ruffle fat appeared to be smaller, but these differences were not statistically significant. There were no apparent differences among treatment groups for the other criteria that were measured.

Further studies were conducted in 1960 (*79*) in which improved bermudagrass hay was used as the roughage portion of the rations. A high-roughage ration and a 60-percent concentrate ration were fed after being ground, ground and dry heated (125° to 150° F.), pelleted, and pelleted and reground.

Composition of the rations was as follows:

Feeds used:	*Ration No. 55 (percent)*	*Ration No. 56 (percent)*
Bermudagrass hay	96	38
Molasses	4	4
Corn	-------	48
Linseed meal	-------	5
Cottonseed meal	-------	5

Their chemical composition is shown in table 9.

TABLE 9.—*Chemical composition of rations (dry basis)*

Ration No.	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash	Kilocalories per gram
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	
55	15. 05	2. 17	29. 59	47. 60	5. 59	4. 603
56	15. 72	2. 99	14. 60	62. 86	3. 83	4. 586

All ration treatments were finely ground (⅜-inch screen). However, further grinding undoubtedly occurred during the pelleting and regrinding processes. With the exception of the pellets, all rations were very dusty. The results are presented in table 10. The trends observed are in good agreement with previous observations at Beltsville, Front Royal, and various experiment stations; that is, feed consumption and average daily gains increased when animals were fed a high-roughage ration in the pelleted or pelleted-and-reground form. Gains were nearly identical for the groups consuming the low-roughage ration, but the pellet-fed steers consumed less feed. The only sta-

tistically significant difference was between the average daily gains for steers consuming the low- compared with the high-roughage ration.

TABLE 10.—*Performance of steers fed high- and low-roughage rations in various forms*

[122-day feeding period, which followed a 28-day adjustment period]

Ration and treatment	Steers	Initial weight	Final weight	Total gain	Average daily gain [1]	Feed per day	Feed per pound of gain
	Number	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
High-roughage (ration 55):							
Ground	3	773	872	99	0.81	15.4	19.0
Ground and heated	3	782	887	105	.86	15.2	17.7
Pelleted	3	782	928	146	1.19	17.0	14.3
Pelleted and reground	3	801	940	139	1.14	18.7	16.1
Average	------	785	907	126	[a]1.01	16.6	16.4
Low-roughage (ration 56):							
Ground	3	844	1,023	179	1.46	16.6	11.4
Ground and heated	3	800	973	173	1.42	17.2	12.1
Pelleted	3	759	940	181	1.49	14.3	9.6
Pelleted and reground	3	793	979	186	1.52	16.4	10.8
Average	------	793	979	180	[b]1.47	16.1	11.0

[1] Values with unlike superscripts in the same column are significantly different at the 5-percent level.

Table 11 presents similar data but includes the 28-day adjustment period in the calculations. The performance trends appear similar for the steers fed the high-roughage rations, but are markedly different for the steers fed the low-roughage rations. The lower gains for the pellet-fed steers reflect the relatively slow adjustment to the pelleted form of the low-roughage ration. Apparently the switch from late-season pasture to low-roughage pellets was a difficult transition for the steers used in this experiment.

During the experiment, rumen liquor samples were obtained by means of a stomach tube. Each steer was sampled twice during the experiment and the volatile fatty acid content of the rumen liquor was determined by means of column chromatography (Neish, *73*). The average concentrations and proportions are presented in table 12. The concentrations of butyric plus higher acids and propionic acid were higher in the rumen liquor of the animals consuming the low-roughage ration. The concentration of these same acids was also higher in the rumen liquor of the animals consuming the ration that had been pelleted and reground. The latter observation may also be true for the butyric acid in the rumen liquor of the steers fed the pelleted ration as compared with those fed the ground and the ground-and-heated rations. The concentration of acetic acid was relatively uniform regardless of the form or type of ration being fed. An exception was the higher value when the high-roughage, reground ration was fed. The variations in proportions of acids present simply reflect the variations in concentration mentioned above.

TABLE 11.—*Performance of steers fed high- and low-roughage rations in various forms*

[150-day feeding period, including adjustment period]

Ration and treatment	Steers	Initial weight	Final weight	Total gain	Average daily gain	Feed per day	Feed per pound of gain
High-roughage (ration 55):	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Ground	3	755	872	117	0. 78	14. 7	18. 8
Ground and heated	3	775	887	112	. 75	14. 4	19. 2
Pelleted	3	777	928	151	1. 00	15. 7	15. 7
Pelleted and reground	3	793	940	147	. 98	17. 8	18. 2
Average		775	907	132	. 88	15. 7	17. 8
Low-roughage (ration 56):							
Ground	3	789	1, 023	234	1. 56	16. 0	10. 3
Ground and heated	3	782	973	191	1. 27	16. 3	12. 8
Pelleted	3	796	940	144	. 96	13. 4	14. 0
Pelleted and reground	3	777	979	202	1. 34	16. 0	11. 9
Average		786	979	193	1. 29	15. 4	11. 9

TABLE 12.—*Volatile fatty acid concentrations in rumen liquor of steers consuming high- and low-roughage rations in various forms*

Ration and treatment	Butyric plus higher acids		Propionic		Acetic		Total
	mM/l.	*% total acids*	*mM/l.*	*% total acids*	*mM/l.*	*% total acids*	*mM/l.*
High-roughage (ration 55):							
Ground	10. 6	14. 4	12. 4	16. 8	50. 7	68. 9	73. 6
Ground and heated	10. 4	13. 1	14. 0	17. 6	55. 4	69. 4	79. 8
Pelleted	12. 9	15. 6	13. 4	16. 1	56. 7	68. 3	83. 1
Pelleted and reground	15. 0	13. 5	19. 8	17. 8	76. 8	68. 8	111. 6
Average	12. 2	14. 1	14. 9	17. 2	59. 9	68. 8	87. 0
Low-roughage (ration 56):							
Ground	18. 4	17. 0	30. 9	28. 7	60. 6	56. 1	108. 1
Ground and heated	17. 2	16. 0	31. 2	28. 9	59. 5	55. 2	107. 9
Pelleted	24. 6	20. 1	28. 7	23. 5	69. 2	56. 5	122. 6
Pelleted and reground	36. 1	26. 6	39. 9	29. 6	59. 2	43. 9	135. 1
Average	24. 1	20. 3	32. 5	27. 4	62. 1	52. 3	118. 7

During the latter part of the feeding trial, samples of the high-roughage rations were taken at random for subsequent digestion trials with sheep.[5] The chemical compositions of the rations and the diges-

[5] Lindahl, I., and Jackson, C. 1961. Unpublished.

tion coefficients are presented in tables 13 and 14. The pelleted and the pelleted-and-reground rations fed during the digestion trial were lower in crude protein (2.0 percentage units) than the ground and the ground-and-heated rations. This difference was by no means as clear from the chemical analyses of the samples taken during the feeding trial, although the protein values were slightly lower (0.5 of a percentage unit) for the pelleted rations. Digestion coefficients for dry matter, crude protein, and crude fiber were significantly lower (at the 5-percent level) for the pelleted and the pelleted-and-reground rations. Digestible gross energy was also less digestible than in the ground ration but no different than that of the ground-and-heated ration. Digestible ether extract and N-free extract were similar for all treatments.

TABLE 13.—*Chemical composition of the high-roughage ration fed during digestion trial with sheep*

Ration and treatment	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Ash	Kilocalories per gram
Ration 55:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	
Ground	14. 28	2. 37	28. 12	49. 54	5. 18	4. 579
Ground and heated	14. 72	2. 42	28. 20	49. 48	5. 18	4. 540
Pelleted	12. 90	2. 17	27. 60	52. 71	4. 62	4. 582
Pelleted and reground	12. 70	2. 18	27. 86	52. 49	4. 77	4. 557

TABLE 14.—*Digestion coefficients for the high-roughage ration as determined with sheep* [1]

Treatment	Dry matter	Crude protein	Ether extract	Crude fiber	Nitrogen-free extract	Gross energy
Ration 55:	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Ground	[a] 54. 5	[a] 65. 0	47. 7	[a] 52. 8	52. 7	[a] 52. 5
Ground and heated	[a] 54. 3	[a] 64. 9	48. 0	[a] 52. 5	52. 3	[ab] 51. 1
Pelleted	[b] 51. 0	[b] 60. 0	45. 5	[b] 47. 3	51. 1	[b] 48. 9
Pelleted and reground	[b] 50. 5	[b] 58. 7	44. 6	[b] 47. 5	50. 6	[b] 48. 5
Mean	52. 1	62. 2	46. 5	50. 0	51. 7	50. 3

[1] Figures in the same column with unlike superscripts are significantly different at the 5-percent level.

The depression in crude fiber digestibility associated with pelleting is in agreement with other reports. The increase in the apparent digestibility of ether extract when pelleting alfalfa (Reynolds and Lindahl, *82*) was not observed in this bermudagrass study. Depressed crude protein digestibility when the ration was pelleted is an effect opposite to that observed by Meyer (*68*), who fed pelleted alfalfa to

sheep but is in agreement with that by Clanton, Peden, and Matsushima (*23*); Alexander et al. (*4*); and Blaxter and Graham (*12*). One thing that does appear clear is the good quality of the bermudagrass hay being fed.

Samples of the rations were screened for particle size. An attempt to break up the pellets without further grinding was not successful. Approximately 30 percent of the samples from each of the rations passed through an 80-mesh screen.

At the end of the trial, one animal from each of the groups fed the rations in the ground and pelleted forms was slaughtered and the rumen and contents observed. Color and papillary development appeared normal. The weight of the empty rumens was greater for the animals that had consumed the high-roughage ration.

Beltsville, Md., 1960–61

Since the steers fed individually on the high- and low-bermudagrass rations did not perform as well as expected, a group feeding trial was conducted in 1960–61 (*81*). A 60-percent bermudagrass ration was fed ground (1-inch screen), ground and heated (240° to 260° F.), and pelleted (⅜-inch die). A 60-percent ground (1½-inch screen) alfalfa ration was fed as a positive control. Although the bermudagrass ration was originally ground through a 1½-inch screen, it was coarser than the alfalfa. When ground through a 1-inch screen, the physical state of the bermudagrass ration more closely approximated that of the alfalfa ration. A soil sterilizer (autoclave) was used to heat the bermudagrass ration (4 hours), which was subsequently dried in a convection forage-drying oven heated with steam pipes.

The animals that were fed *ad libitum* in groups of seven were allowed no adjustment period. Their beginning and end weights were averaged from weights taken on 2 alternate days and weights were recorded every 2 weeks during the experiment. A mineral mixture of 1-to-1 trace mineralized salt and bone meal was freely available to each group of animals. At the conclusion of the study all animals were given slaughter grades and the pelleted-and-ground bermudagrass-fed groups were slaughtered to determine carcass grades and to see if there were any other apparent carcass differences. Results with the following rations are summarized in table 15.

Feeds used:	*Ration No. 72 (percent)*	*Ration No. 73 (percent)*
Alfalfa hay	------	60
Bermudagrass hay	60	-----
Corn	36	36
Molasses	4	4

Grinding, heating, or pelleting had no marked effect upon the chemical composition of the bermudagrass-corn ration as determined (table 16). The differences in composition that do exist apparently resulted from a lower rate of consumption by the animals on the heated ration. Since the earlier batches of feed prepared were lower in protein, this is reflected in the average value for the heated ration.

The alfalfa-corn ration was appreciably higher in crude protein than the bermudagrass-corn ration. Steers fed the alfalfa ration made significantly greater gains. Those fed the chopped and pelleted

TABLE 15.—*Performance of steers fed a bermudagrass-corn and an alfalfa-corn ration*

Ration No. and treatment	Steers	Initial weight	Final weight	Total gain [1]	Average daily gain [1]	Slaughter grade [1]	Feed per day	Feed per pound of gain
Bermudagrass-corn (ration 72):	*Number*	*Pounds*	*Pounds*	*Pounds*	*Pounds*		*Pounds*	*Pounds*
Chopped [2]	7	624	871	[a] 247	[a] 1. 79	[a] Good	19. 97	11. 16
Heated [3]	7	608	[4] 648	[b] 40	[b] 29	[b] Utility	[5] 12. 29	
Pelleted [6]	7	604	880	[a] 276	[a] 2. 00	[a] Good	18. 77	9. 39
Alfalfa-corn (ration 73): chopped [7]	7	611	952	[c] 341	[c] 2. 47	[a] Good	24. 56	9. 94

[1] Figures in the same column with unlike superscripts are significantly different at the 5-percent level.

[2] Chopped through 1-inch screen.

[3] Autoclaved at 20 p.s.i. pressure, at approximately 260° F. for 4 hours.

[4] Promine or soybean oil meal added during last 47 days of the 138-day feeding period.

[5] Does not include 196 pounds Promine and 315 pounds soybean meal fed during the last 47 days of the trial.

[6] Ground through ⅜-inch screen, ⅜-inch pellet.

[7] Chopped through 1½-inch screen.

TABLE 16.—*Chemical composition of the rations (dry basis)*

Ration No. and treatment	Crude protein	Ether extract	Ash	Kilocalories per gram
Bermudagrass-corn (ration 72):	*Percent*	*Percent*	*Percent*	
Ground	11. 77	2. 81	3. 32	4. 530
Heated	11. 16	2. 91	3. 82	4. 512
Pelleted	11. 91	3. 11	3. 15	4. 569
Alfalfa-corn (ration 73)	13. 64	2. 80	4. 82	4. 459

bermudagrass significantly outgained the steers consuming the heated bermudagrass ration. Steers fed the heated bermudagrass ration lost 1.37 pounds a day for 84 days. From the 56th to the 70th day, 136 grams of urea was added to the feeder daily; from the 70th to the 84th day, 31.5 grams of lysine was added to the feeder daily; and finally 10-percent molasses was added to the ration. These additions had no apparent effect upon feed consumption or body-weight gains. However, when Promine [6] was added to the feeder at the rate of a pound per animal per day, the response of the animals was immediate and marked. After 28 days, the Promine was replaced by an equivalent amount of protein from soybean meal which was added at the rate of 2.5 pounds per animal per day. During the period of protein supplementation the animals gained 2.87 pounds per day (fig. 1). Intake increased from 10.1 to 15.6 pounds per day excluding the protein supplement. Expressed as a percentage of average body weight, the feed intakes increased from 1.83 to 2.73 percent.

A rat-growth study conducted by Cabell (cited by Putnam and Davis, *81*) gave results similar to those of the cattle trial with less growth by the rats consuming the diet containing the heated bermudagrass-corn ration. The rats on the diet containing the ground bermudagrass-corn ration and the alfalfa-corn ration performed similarly, whereas rats consuming the diet containing the pelleted-and-reground bermudagrass-corn ration made the greatest and most efficient gains. Alteration of the protein quality or availability by the heat treatment was suspected. These suspicions were further confirmed by the chemical analyses conducted on these rations by Van Soest (*91*) and finally by the cattle response to protein supplementation which has already been cited. Van Soest observed that the solubility of the protein in detergent solutions was adversely affected by the heat treatment.

At the conclusion of the feeding trial, a sufficient amount of the ground and heated bermudagrass-corn rations was saved for digestion and nitrogen balance studies. Table 17 summarizes these results. As had been anticipated, the digestibility of the dry matter and crude protein as well as the nitrogen balance were decreased when the heated feed was fed.

[6] Mention of specific products does not imply recommendation by the U.S. Department of Agriculture over similar products not mentioned.

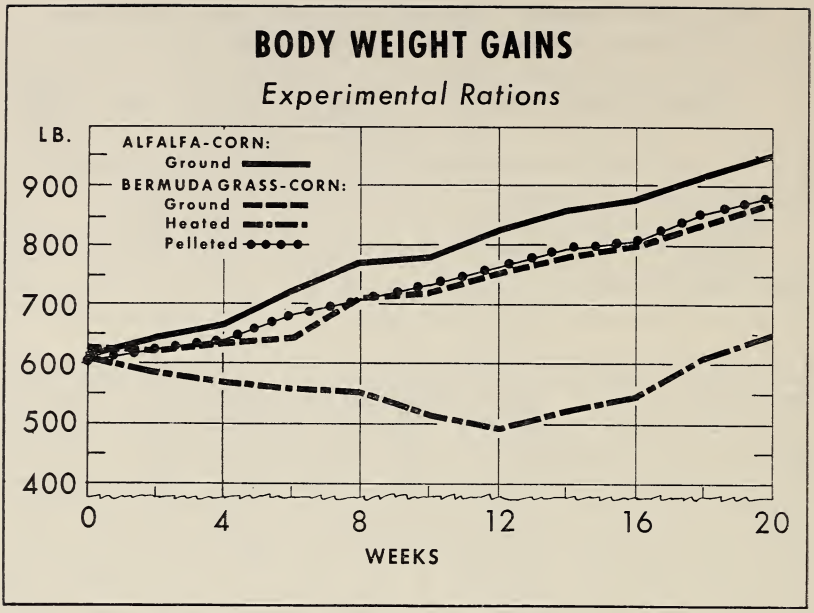

FIGURE 1.—Effect of feeding experimental rations on body weight gains.

TABLE 17.—*Digestion coefficients and nitrogen balance values when feeding chopped and heated bermudagrass-corn rations to steers* [1]

Ration No. and treatment	Dry matter	Crude protein	Nitrogen balance
Ration 72:	*Percent*	*Percent*	*Grams per day*
Chopped	71. 4	67. 4	+0. 4
Heated	63. 9	40. 7	−3. 3

[1] Each value represents an average of two observations.

The average slaughter grade was significantly lower for the steers fed the heated ration. The difference between the mean grades for steers fed the ground or pelleted bermudagrass-corn rations and the alfalfa-corn ration approached the 5-percent level of significance.

As observed before, there was no difference in dressing percentage. However, in contrast to earlier results, the differences in rumen, heart, liver, and lung weights were small and not significant (table 18). The weight of the reticulo-rumen expressed as a percentage of the gastrointestinal tract was significantly greater (at the 10-percent level) for the pellet-fed animals, as it was in the earlier trial.

Since the steers were group fed, no tests of significance were conducted upon the values for feed intakes or feed consumed per pound of grain. However, most of the differences in average daily gains may be related to average feed consumption. The alfalfa-corn ration was consumed in twice the quantities of the heated ration and in quan-

TABLE 18.—*Carcass data on steers fed pelleted and nonpelleted rations, 1961*

Ration No. and treatment	Steers	Cold carcass weight	Dressing	Reticulorumen [1 2]	Rumen [3]	Heart [3]	Liver [3]	Lung [3]
	Number	*Pounds*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Ration 72:								
Pellet	7	455	54. 5	34. 2*	3. 55	0. 76	2. 12	1. 92
Ground	7	458	54. 6	32. 1*	3. 35	. 72	2. 20	1. 87

[1] *=Significantly different at the 10-percent level.
[2] Values are expressed as a percentage of the gastrointestinal tract weight.
[3] Values are expressed as a percentage of the cold carcass weight.

tities approximately 25 percent greater than the ground or pelleted bermudagrass-corn ration. Nevertheless, the feed required per pound of gain was no more for the pelleted ration than for the alfalfa ration and was nearly 20 percent less than for animals on ground bermudagrass ration. This trend is in agreement with the results of the earlier trials at Beltsville, Front Royal, and Fort Reno. The reasons for the increased efficiency have yet to be determined. (In addition, the results with the heated ration raise some questions regarding the protein needs of ruminants.)

In a short-term finishing experiment at Beltsville [7] a complete concentrate ration (cracked corn and soybean meal) in meal form was compared with the same ration fed as a pellet. Significantly less feed ($P<.01$) was consumed by the pellet-fed steers and there were no significant differences in average daily gains or feed consumed per pound of gain (table 19).

TABLE 19.—*Performance of steers fed an all-concentrate ration of cracked corn and soybean meal as a pellet or a meal* [1]

Treatment	Steers	Average daily gain	Feed consumed per day [2]	Feed per pound of gain
	Number	*Pounds*	*Pounds*	*Pounds*
Pellet	10	1. 9	14. 4***	8. 2
Meal	10	2. 4	16. 9***	7. 6

[1] The 70-day experimental period followed a 7-day adjustment period.
[2] ***=Significantly different at the 1-percent level.

DISCUSSION

Observations on pellet stability as affected by the additions of various feedstuffs to cottonseed meal or alfalfa meal illustrate the wide variations to be expected when pelleting mixed rations. Unfor-

[7] Bond, J., and Davis, R. E. 1961. Unpublished.

tunately, additional variations may be expected between batches of the same ration. Such conditions may have contributed to conflicting experimental results reported in the literature.

Feeding trial data have been relatively uniform and have been in accord with the results of contemporary work carried out at other stations. Attempts to relate the increased feed efficiency when mixed rations were pelleted to the effects of heat were unsuccessful. However, studies employing shorter term exposures of feed to temperatures bracketed by these studies (120° to 260° F.) could still supply useful information.

The reluctance of one experimental group of animals to consume the pelleted ration when it was first offered illustrates a problem which could be of importance under practical conditions.

The reasons for the relatively larger reticulo-rumens in the pellet-fed animals are not clear. Feed intake was less and data in the literature suggest that rumination was probably decreased and rate of passage was increased. The effect on rumen fill is not known. More information is needed.

The results of the fatty acid and digestibility studies were in general agreement with previous reports.

SUMMARY

Results are presented of 12 experiments on feeding pelleted rations to cattle. The experiments were conducted by the Beef Cattle Research Branch at Beltsville, Md., Tifton, Ga., Front Royal, Va., and at Fort Reno, Okla.

Pelleting rations usually resulted in equal or better steer gains and approximately 10 percent less feed required per pound of gain. Feed intake increased when high-roughage rations were pelleted, but decreased when high-concentrate rations were pelleted. Length of adjustment period as well as nutritional background may have a marked effect upon the apparent response to pellet feeding.

Pellet-fed steers tended to have a heavier reticulorumen when its weight was expressed as percentage of the weight of the gastrointestinal tract. In one trial, the weight values for the rumen, heart, and liver were greater for the pellet-fed steers when weight of the organs was expressed as a percentage of the cold carcass weight. There was no such trend in a second trial.

Ruminal volatile acids and digestibility values were determined in one trial. The molar percentage of butyric plus higher acids tended to be greater in rumen liquor of steers fed pelleted and pelleted-and-reground rations. Digestible dry matter, crude protein, crude fiber, and energy were depressed when a high-roughage ration was pelleted or pelleted and reground.

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